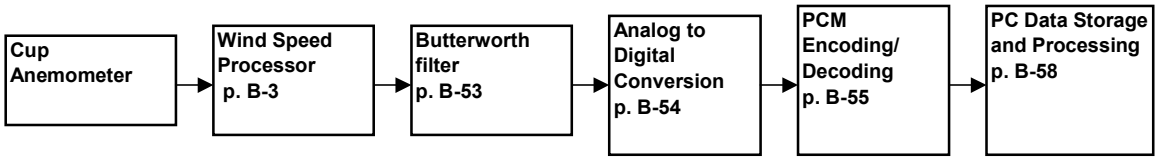
Appendix B

Instrumentation, Data Collection, and Data Processing for Phases III and IV

Anemometers (Cup)

Channel	ID Code	Description
300	LMWS24M	Local met wind speed, 24.38 m
302	LMWS17M	Local met wind speed, 17.02 m (hub height)
304	LMWS10M	Local met wind speed, 10.06 m
306	LMWS2M	Local met wind speed, 2.4 m
308	NLMWS17M	North local met wind speed, 17.02 m (hub height)
314	SLMWS17M	South local met wind speed, 17.02 m (hub height)

Location	Met towers located 1.5D (15 m) upwind of turbine
Measurement type and units	Wind speed, m/s
Sensor description	Cup anemometer DC pulse output, photo chopper type Distance constant = 1.5 m Threshold = 0.45 m/s Accuracy = ±1% of true, certified at 6.70 m/s and 25.03 m/s Met One Instruments Model: 1564B (wind speed sensor), 170-41 (standard plastic cup set)



Wind Speed Processor

Location	Met rack in data shed
Range	0 to 50 m/s = 0 to 5 Volts (Established with the following switch settings: S2 = 1,4,7; S3 = 5)
Resolution	10 m/s / Volt
Output level	0-5 Vdc
Nonlinearity	±0.25% max
Calibration method	Manufacturer specifications (M1) and electronic path calibration (E1)
Description	Wind speed processor Met One Instruments Model: 49.03A (rack mount), 21.11 (processor), 48.11B (power supply)

Calibration Procedure

Manufacturer specifications - (M1)

1. A wind tunnel calibration was performed by Met One Instruments before installation of each anemometer. The correlation between the serial numbers of the cup assembly and the anemometer paired for calibration was maintained when installed in the field.
2. The wind speed processor is adjusted as follows:
   a. With mode switch set to LO, adjust voltage to 0 V ± 1 mV.
   b. With mode switch set to HI, adjust voltage to 3.810 V ± 1 mV (This value was specified by the manufacturer for a range of 0 m/s to 50 m/s.).
   c. Set mode switch to OP for normal operation.
3. Enter the slope (50 m/s / 5V) and the single point offset (0 m/s / 0 V) in the appropriate columns of *calconst.xls* (See p. B-69).

Electronic path calibration - (E1)

1. Modify *vbl.lst* so that the wind speed channels are listed at the top of the file. Set NV (number of variables) in the first line to the number of channels to be calibrated, and insure that the correct PCM stream is specified in *gencal.cap* (all meteorological measurements are on PCM stream 3).
2. Connect the precision voltage generator to the processor output.
3. Run the *gc.bat* batch file which invokes both *gencal.exe* and *genfit.exe*. Collect samples for voltages ranging from 0 to 4.5 V in 0.5 V increments with two repetitions at each voltage level. The recorded input and output values are stored in the **.cao* input file. *Genfit.exe* computes slopes and offsets of the electronic path from the processor output to the computer in units of V/count and V respectively. These values are stored in a temporary header file, **.hdr*. These slope and offset values are combined with the manufacturer provided slope and offset stored in *calconst.xls* during the *buildhdr.bat* process to obtain units of engineering unit/count and counts respectively.

Calibration frequency

The anemometers were calibrated prior to each series of data collection or upon replacement due to cup damage. Processors were adjusted prior to each series of data collection which lasted 2 months at most. On occasion, the processors were adjusted during a series of data collection.

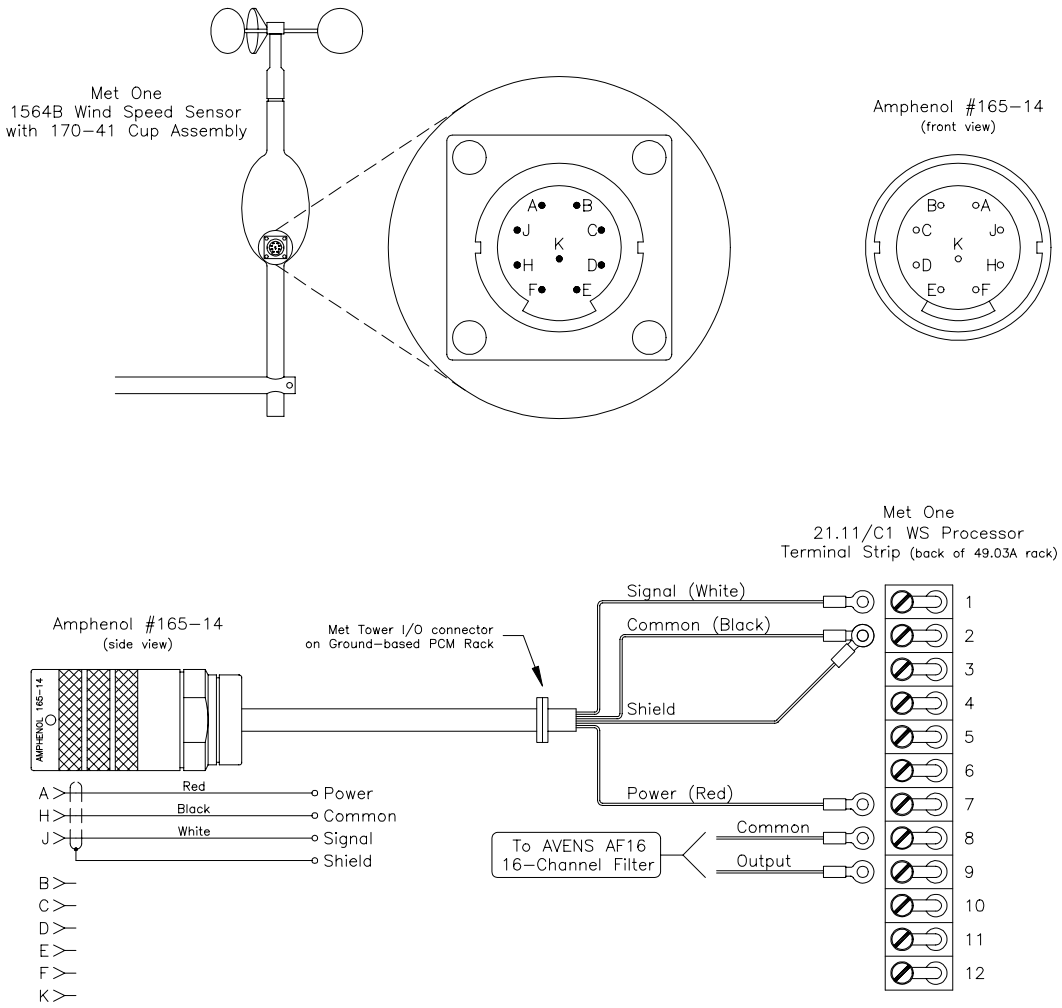
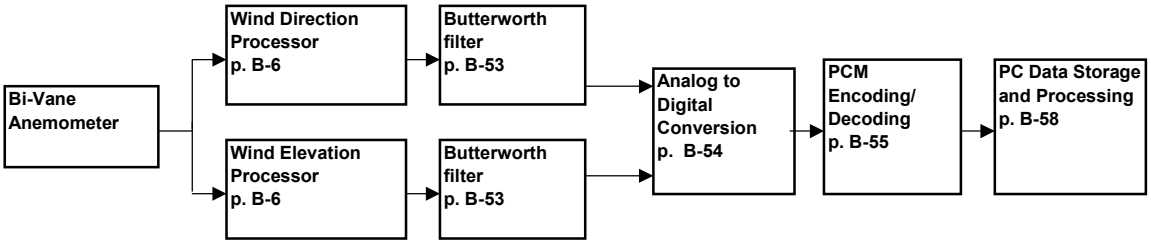


Figure B.1. Cup anemometer wiring diagram.

Anemometers (Bi-Vane)

Channel	ID Code	Description
310	NLMWD17M	North local met wind direction, 17.02 m (hub height)
312	NLMWE17M	North local met wind elevation angle, 17.02 m (hub height)
316	SLMWD17M	South local met wind direction, 17.02 m (hub height)
318	SLMWE17M	South local met wind elevation angle, 17.02 m (hub height)

Location	North and South met towers located 1.5D (15 m) upwind of turbine
Measurement type and units	Wind direction and wind elevation angles, degrees
Sensor description	Bi-vane anemometer Distance constant = 1m (both wind direction and elevation) Threshold = 0.45 m/s (both wind direction and elevation) Accuracy = ±2° (both wind direction and elevation) Met One Instruments Model: 1585



Wind Direction Processor

Channel	ID Code	Description
310	NLMWD17M	North local met wind direction, 17.02 m (hub height)
316	SLMWD17M	South local met wind direction, 17.02 m (hub height)

Location	Met rack in data shed
Range	0° to 360° = 0 V to 5 V
Resolution	72°/Volt
Calibration method	Manufacturer specifications (M2), single point offset determination (S1), and electronic path calibration (E1)
Output level	0-5 Vdc
Linearity	±0.1% max
Description	Wind direction processor Met One Instruments Model: 49.03A (rack mount), 21.21 (processor), 48.11B (power supply)

Calibration Procedure

Manufacturer specifications - (M2)

1. The bi-vane anemometers were calibrated by Met One Instruments according to manufacturer specifications before installation.
2. The wind direction processor is adjusted as follows:
   a. With mode switch set to LO, adjust voltage to 0 V ± 1 mV.
   b. With mode switch set to HI, adjust voltage to 5 V ± 1 mV.
   c. Set mode switch to OP for normal operation.
3. Enter the slope (360°/5V) in the slope column of *calconst.xls*

Single point offset determination - (S1) - (This is a two-person operation requiring one person in the man-lift to position the vanes and one person on the ground to record the voltages.)

1. Man-lift person notifies ground person which transducer is to be calibrated and aligns the vane by eye with the North met tower (292° true north).
2. The ground person uses the voltmeter to record the vane position. The average voltage reading is inserted in the single point offset column of *calconst.xls*.

Electronic path calibration - (E1)

1. Modify *vbl.lst* so that the wind direction channels are listed at the top of the file. Set NV (number of variables) in the first line to the number of channels to be calibrated, and insure that the correct PCM stream is specified in *gencal.cap* (all meteorological measurements are on PCM stream 3).
2. Connect the precision voltage generator to the processor output.
3. Run the *gc.bat* batch file which invokes both *gencal.exe* and *genfit.exe*. Collect samples for voltages ranging from 0 to 4.5 V in 0.5 V increments with two repetitions at each voltage level. The recorded input and output values are stored in the **.cao* input file. *Genfit.exe*

computes slopes and offsets of the electronic path from the processor output to the computer in units of V/count and V respectively. These values are stored in a temporary header file, **.hdr*. These slope and offset values are combined with the manufacturer provided slope and offset stored in *calconst.xls* during the *buildhdr.bat* process to obtain units of engineering unit/count and counts respectively.

Calibration frequency

The anemometers were calibrated by the manufacturer prior to Phase III data collection. The north local met tower bi-vane was calibrated by the manufacturer prior to Phase IV data collection. Amplifier adjustment, offset determination, and electronics path calibrations were performed prior to each series of data collection which lasted less than 2 months.

Wind Elevation Processor

Channel	ID Code	Description
312	NLMWE17M	North local met wind elevation angle, 17.02 m (hub height)
318	SLMWE17M	South local met wind elevation angle, 17.02 m (hub height)

Location	Met rack in data shed
Range	-60° to 60° (+ indicates ascending air)
Resolution	24°/Volt (nominal)
Calibration method	Manufacturer specifications (M3), single point offset determination (S2), and electronic path calibration (E1)
Output level	0-5 Vdc
Linearity	±0.1% max
Sensitivity	4.16 mV/Hz nominal
Span Range	±25% nominal
Description	Wind elevation processor
	Met One Instruments Model: 49.03A (rack mount), 21.24 (processor), 48.11B (power supply)

Calibration Procedure

Manufacturer specifications - (M3)

1. The bi-vane anemometers were calibrated by Met One Instruments according to manufacturer specifications before installation.
2. The wind elevation processor is adjusted as follows:
    a. Determine LO and HI voltages using sensitivity (SEN [Hz/°]) provided by manufacturer and the full scale elevation angle (FS = 60°) in the following formulae:

$$ELO = 2.5 * (SEN * FS - 600) / (SEN * FS),$$

$$EHI = 2.5 * (SEN * FS + 600) / (SEN * FS).$$

    b. With mode switch set to LO, adjust voltage to ELO ± 1 mV.
    c. With mode switch set to HI, adjust voltage to EHI ± 1 mV.
    d. Set mode switch to OP for normal operation.
3. Enter the slope (24°/Volt) in the appropriate column of *calconst.xls.* The values used during Phases III and IV were determined in an unknown manner, but both bi-vane slopes were within 0.003°/Volt of 24 °/Volt.

Single point offset determination - (S2) -

(This is a two-person operation requiring one person in the man-lift to position the vanes and one person on the ground to operate the computer.)

1. Man-lift person notifies ground person which transducer is to be calibrated and, using an Angle-star, positions the vane at 0°.
2. The ground person uses the voltmeter to record the vane position. The average voltage value is inserted in the appropriate column of *calconst.xls*.

Electronic path calibration - (E1)

1. Modify *vbl.lst* so that the wind elevation channels are listed at the top of the file. Set NV (number of variables) in the first line to the number of channels to be calibrated, and insure that the correct PCM stream is specified in *gencal.cap* (all meteorological measurements are on PCM stream 3).
2. Connect the precision voltage generator to the processor output.
3. Run the *gc.bat* batch file which invokes both *gencal.exe* and *genfit.exe*. Collect samples for voltages ranging from 0 to 4.5 V in 0.5 V increments with two repetitions at each voltage level. The recorded input and output values are stored in the **.cao* input file. *Genfit.exe* computes slopes and offsets of the electronic path from the processor output to the computer in units of V/count and V respectively. These values are stored in a temporary header file, **.hdr*. These slope and offset values are combined with the manufacturer provided slope and offset stored in *calconst.xls* during the *buildhdr.bat* process to obtain units of engineering unit/count and counts respectively.

Calibration frequency

The anemometers were calibrated by the manufacturer prior to Phase III data collection. The North local met tower bi-vane was calibrated by the manufacturer prior to Phase IV data collection. Amplifier adjustment, offset determination, and electronics path calibrations were performed prior to each series of data collection which lasted less than 2 months.

Note: The processor calibration voltages were not updated after the manufacturer calibration performed prior to Phase IV. These voltages were updated prior to the second series of Phase IV during the spring of 1997.

Phase III (1995) and Phase IV (1996)
S/N 055 Sensitivity = 12.75 Hz/deg, ELO = 0.539V, EHI = 4.461V (south met tower)
S/N 056 Sensitivity = 12.20 Hz/deg, ELO = 0.451V, EHI = 4.549V (north met tower)

Second season of Phase IV (1997)
S/N 056 Sensitivity = 12.24 Hz/deg, ELO = 0.458V, EHI = 4.542V (north met tower)

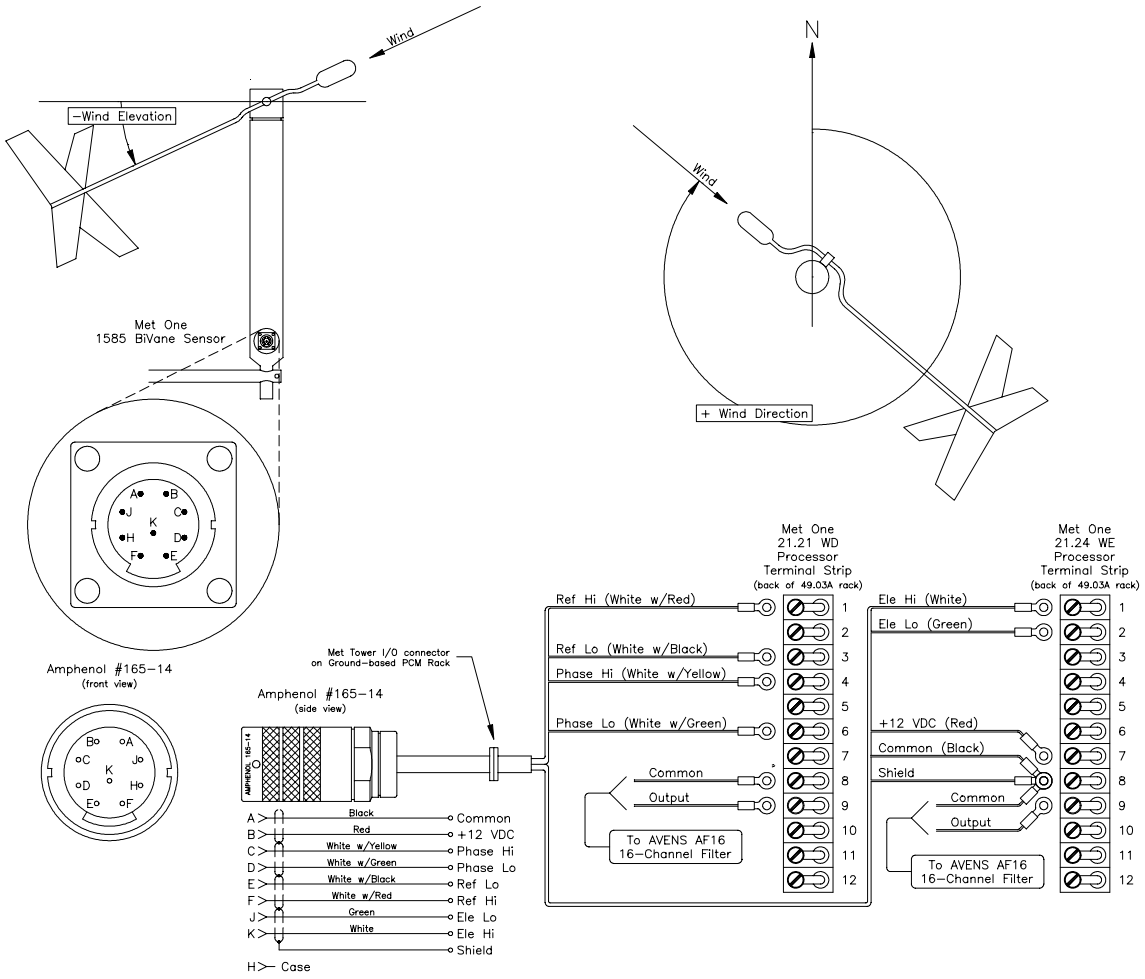
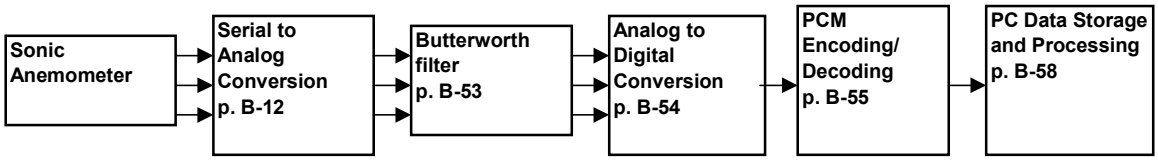


Figure B.2. Bi-vane anemometer wiring diagram.

Channel	ID Code	Description
326	LMSU17M	Local met sonic channel U, 17.02 m (hub height)
328	LMSV17M	Local met sonic channel V, 17.02 m (hub height)
330	LMSW17M	Local met sonic channel W, 17.02 m (hub height)

Location	Local met tower located 1.5D (15 m) upwind of turbine
Measurement type and units	3-D, orthogonal components of wind speed and direction, m/s
Sensor description	3-axis sonic anemometer Accuracy Wind speed, ±1% or ±0.05 m/s Wind direction, ±0.1° Temperature, ± 1% (not recorded) Applied Technologies, Inc. Model: SWS-211/3K



Note: Each of the three wind velocity components is contained in the PCM streams and recorded. Wind speed and direction are determined using these components during post-processing. The sonic's determination of wind speed, wind direction, and temperature is not used.

Sonic Serial to Analog Converter

Channel	ID Code	Description
326	LMSU17M	Local met sonic channel U, 17.02 m (hub height)
328	LMSV17M	Local met sonic channel V, 17.02 m (hub height)
330	LMSW17M	Local met sonic channel W, 17.02 m (hub height)

Location	Met rack in data shed
Range	±50 m/s at ±5 V (U,V); ±15 m/s at ±5 V (W)
Resolution	10 m/s / Volt (U,V); 3 m/s / Volt (W)
Calibration method	Manufacturer specifications (M4) and electronic path calibration (E1)
Input Signal	Serial RS-232C
Output Signal	±5 Vdc
Description	Serial to analog converter
	Applied Technologies, Inc. Model: SA-4

Calibration Procedure

Manufacturer specifications - (M4)

1. A calibration was performed by Applied Technologies before installation of the anemometer.
2. Enter the slope (50 m/s / 5 V for U and V; 15 m/s / 5 V for W) and the offset (0 m/s / 0 V for U, V, and W) in the appropriate columns of *calconst.xls*.
3. Transducer Calibration
    a. Place zero-air chamber over axis to be calibrated. (Note: Ideally this should be done in a controlled environment. Radiation from the sun can heat the inside of the chamber faster than the calibration is performed. If this is done outside, a cloudy day is preferable, and the ambient temperature must be greater than 0°C.)
    b. Enter the appropriate number in the "DATA ENTRY" thumbwheel. (U = 01, V = 02, W = 03)
    c. Press the "CALIBRATION" switch and enter the ambient air temperature (within ±1°C) once the "TEMP" light is illuminated. Depress the "CALIBRATION" switch once the temperature is entered.
    d. The "TEST" light will blink twice and the new transducer calibration is complete.

Electronic path calibration - (E1)

1. Modify *vbl.lst* so that the sonic channels are listed at the top of the file. Set NV (number of variables) in the first line to the number of channels to be calibrated, and insure that the correct PCM stream is specified in *gencal.cap* (all meteorological channels are on PCM stream 3).
2. Connect the precision voltage generator to the processor output.
3. Run the *gc.bat* batch file which invokes both *gencal.exe* and *genfit.exe*. Collect samples for voltages ranging from –4.5 to 4.5 V in 1 V increments with two repetitions at each voltage level. The recorded input and output values are stored in the **.cao* input file. *Genfit.exe*

computes slopes and offsets of the electronic path from the processor output to the computer in units of V/count and V respectively. These values are stored in a temporary header file, **.hdr*. These slope and offset values are combined with the manufacturer provided slope and offset stored in *calconst.xls* during the *buildhdr.bat* process to obtain units of engineering unit/count and counts respectively.

Calibration frequency

The transducers were calibrated and an electronic path calibration was performed prior to each series of data collection which lasted less than 2 months.

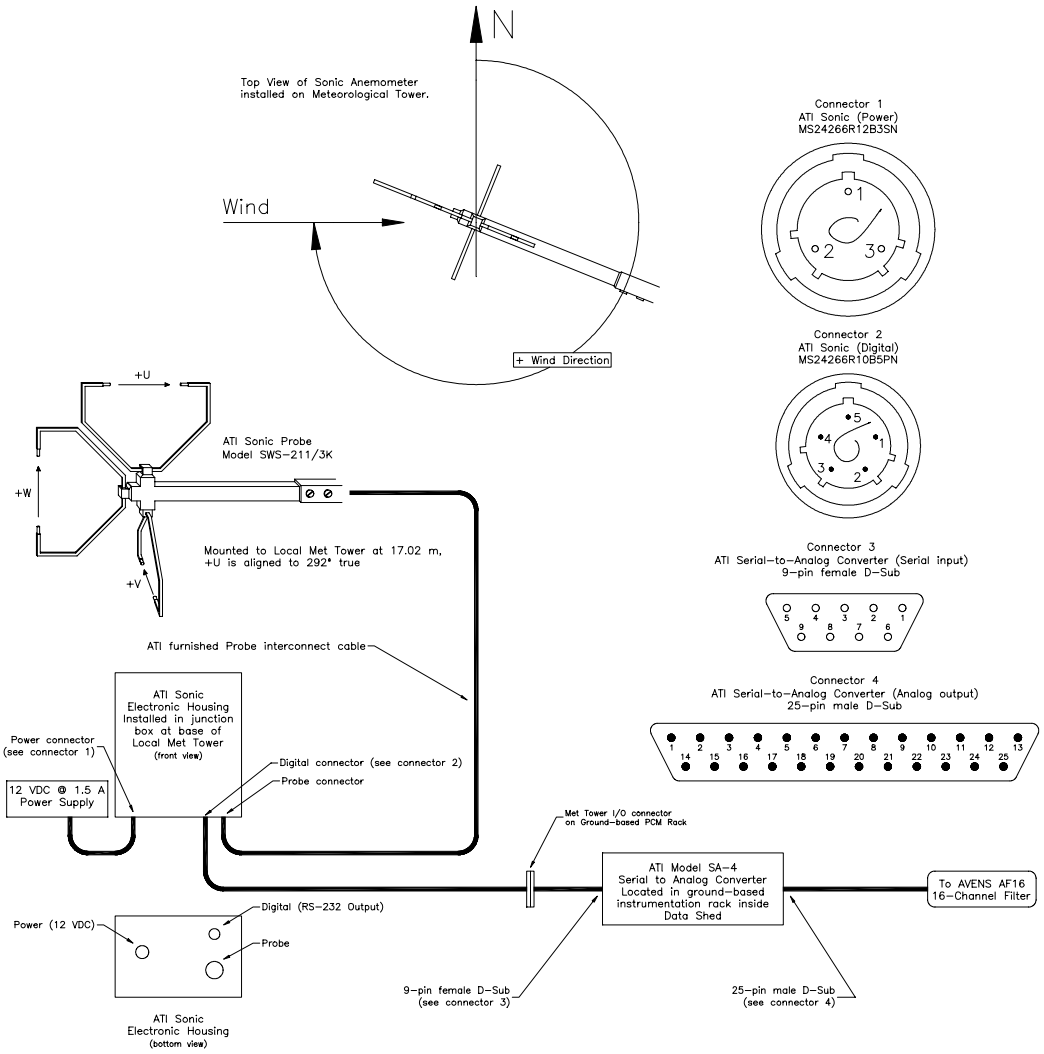
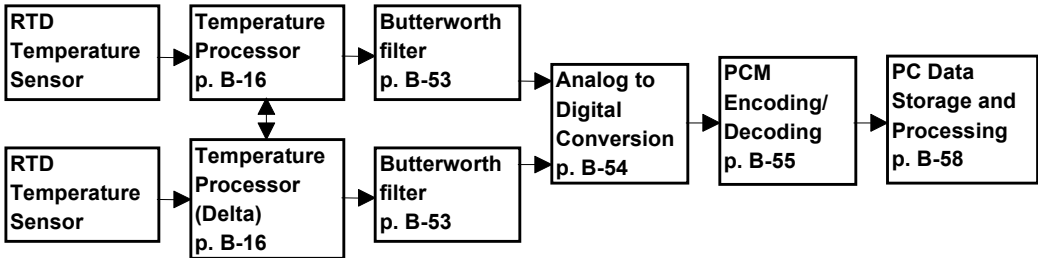


Figure B.3. Sonic anemometer wiring diagram.

Temperature (Ambient)

Channel	ID Code	Description
320	LMT2M	Local met temperature 2.4 m
322	LMT24M	Local met temperature 24.48 m (data1-data7)
322	LMDT	Local met Δ temperature, 24.48 m - 2.4 m (data8-Phase IV)

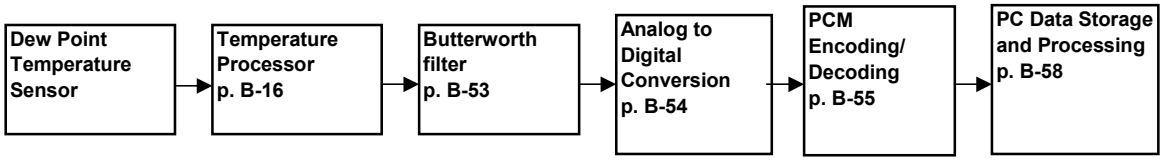
Location	Local met tower located 1.5D (15 m) upwind of turbine
Measurement type and units	Ambient temperature or delta temperature, °C
Sensor description	Platinum resistance element nominally 80Ω - 120 Ω for -50°C to 50°C R_o = 100±0.1Ω at 0°C Time constant < 10 seconds Met One Instruments Model: T-200 (sensor), 327C (aspirated radiation shield)



Note: Sensor is mounted in an aspirated radiation shield. If the aspirating fan malfunctions, a light on the met rack is illuminated, an audible alarm sounds, and data collection is halted.

Temperature (Dew Point)

Channel	ID Code	Description
324	LMDP2M	Local met dew point 2.4 m
Location		Local met tower located 1.5D (15 m) upwind of turbine
Measurement type and units		Dew point temperature, °C
Sensor description		Dew point temperature sensor DP systematic error = ±0.75°C DP random error = ±0.50°C Met One Instruments Model: DP200B (sensor), 327C (aspirated radiation shield)



Note: Sensor is mounted in an aspirated radiation shield. If the aspirating fan malfunctions, a light on the met rack is illuminated, an audible alarm sounds, and data collection is halted.